



Traumatic cardiac arrest

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Purpose of review

This review considers the latest evidence relating to the epidemiology and outcomes, treatment guidelines, diagnostic and therapeutic interventions in traumatic cardiac arrest.

Recent findings

There is variation in the incidence and outcomes of traumatic cardiac arrest which is influenced in part by case definitions. Irrespective of case definitions outcomes from traumatic cardiac arrest are typically worse than those seen from cardiac arrest due to medical causes but not so poor as to consider that treatment is futile. Clinical guidelines focus on the prompt treatment of reversible causes, although evidence that this improves outcomes is limited. Point of care ultrasound to assist with the identification of reversible causes should be limited to experienced operators where there is thought to be a high likelihood of a reversible cause being present. Care should be taken to minimize interruptions in chest compressions during scanning. There is little recent evidence to support specific therapeutic interventions. The role of Resuscitative Endovascular Balloon Occlusion of the Aorta during traumatic cardiac arrest remains to be determined in on-going research.

Conclusion

Trauma related cardiac arrest differs from cardiac arrest due to medical causes. Whilst the core principles of treatment are similar, a higher priority is placed on identifying and treating reversible causes.

Keywords

cardiac arrest, haemorrhagic shock, trauma, traumatic cardiac arrest

INTRODUCTION

The epidemiology and pathophysiology of traumatic cardiac arrest (TCA) differs in several ways from the more common medical causes of cardiac arrest. The population of patients is typically younger and have fewer comorbidities. The causes of TCA (hypovolaemia, tension pneumothorax, hypoxia, cardiac tamponade) are potentially reversible with prompt and effective treatment [1[■]]. These characteristics require special consideration in the approach to resuscitation to deliver the best outcomes. This review will provide an update on the latest evidence relating to the epidemiology and outcomes, clinical treatment guidelines, approaches to assessing the underlying cause and recent developments in the treatment of TCA.

EPIDEMIOLOGY AND OUTCOMES

Trauma and cardiac arrest registries differ in how they define a case of TCA, which can impede comparisons between studies. Over the last 18 months studies have reported outcomes amongst all patients attended by emergency medical services (EMS) [2], only those who received treatment by EMS [3[■]], only

those taken to hospital [4[■]] through to only those who survived to be admitted to intensive care [5]. Survival to discharge rates were lowest in studies that reported all patients (147/3891, 3.7%) [2] and highest in those who limited reporting to those who were admitted to intensive care (13/37, 35%).

This variation in survival rates according to case definition is exemplified in a systematic review and meta-analysis, which identified studies relating to prehospital TCA published between 1995 and 2020 [6[■]]. The review identified 36 studies involving 51 722 patients. Most studies came from Europe and Asia and reported on outcomes following penetrating and blunt trauma. Survival rates varied depending on whether registries included deaths which occurred in the prehospital setting. In studies which

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KEY POINTS

- Variation in outcomes from traumatic cardiac arrest can in part be explained by differences in the populations of patients included by registries.
- Guidelines promote prioritizing treatment of reversible causes, although the evidence supporting such an approach is limited.
- The role of point of care ultrasound during traumatic cardiac arrest is uncertain and its use should be limited to those with appropriate training and skills
- Further research is required to refine the indications and optimize outcomes for resuscitative thoracotomy and resuscitative endovascular balloon occlusion of the aorta.

included prehospital deaths, mortality was high at 97.2% [95% confidence interval (CI) 96.3–98.0]. For studies which excluded prehospital deaths, mortality was lower at 92.3% (95% CI 85.7–96.3). Favourable neurological outcomes also appeared worse in studies which included prehospital deaths 35.8% (95% CI 29.8–42.2) compared to those where prehospital deaths were excluded 49.5% (95% CI 23.3–75.9).

Several studies examined factors associated with improved outcomes. The systematic review summarized above reported improved survival (6.1% vs. 2.4%) and favourable neurological outcomes amongst survivors (57% vs. 38%) in systems, which included an EMS physician response [6[■]]. Doan *et al.* [2] from Queensland Ambulance Service noted improved survival to hospital admission (adjusted odds ratio 2.54 (1.25–5.18) in patients treated by a high acuity response unit comprising of paramedics and advanced clinical practitioners but this did not translate to improved survival at discharge (adjusted odds ratio 2.1 (0.96–2.94).

Other factors associated with better outcomes included younger age [7], female sex [7], lower injury severity [4[■],7], extremity injury [7], arrest witnessed by a clinician [3[■],7,8], bystander cardiopulmonary resuscitation (CPR) [3[■]], an initially shockable rhythm [2,3[■],4[■],6[■],9], advanced airway management [2], intravenous access [2], shorter transfer time [10[■]], reactive pupils [4[■],9], and receiving emergency surgery [7].

CLINICAL TREATMENT GUIDELINES

The evidence base informing current clinical guidelines for TCA are primarily drawn from observational studies or extrapolated from randomized trials involving trauma patients without cardiac arrest [1[■]].

A cross-sectional analysis of EMS protocols and prehospital practice patterns in the USA identified the absence of standardized guidelines for the prehospital management of TCA [11]. The review found wide variation amongst 35 publicly available state protocols for TCA as well as variation in practice amongst EMS clinicians managing these events. The authors call for consistent, standardized, evidence-based guidelines which clarify the optimal management of TCA.

The European Resuscitation Council (ERC) Guidelines provide one such framework for the management of TCA (see Fig. 1) [12[■]]. The guidelines prioritize the identification of potentially reversible causes of cardiac arrest (hypovolaemia, hypoxia, tension pneumothorax, cardiac tamponade) with treatments tailored to the underlying cause (haemorrhage control, oxygenation, relief of tension pneumothorax/tamponade and correction of hypovolaemia). The guidelines highlight the need for appropriate expertise, equipment and environment to deliver time critical interventions. Where injuries incompatible with life (e.g. decapitation, penetrating cardiac injury, loss of brain tissue) or where no signs of life have been present in the preceding 15 min, the guidelines suggest withholding resuscitation.

The French Society of Emergency Medicine and the French Society of Anaesthesia and Intensive Care Medicine developed cognitive aids for trauma management in the form of trauma flow charts with the intension of providing comprehensive visual guidelines for clinicians in the prehospital setting [13[■]]. The flow charts cover similar concepts to the ERC Guidelines, highlighting prioritizing the treatment of reversible causes.

Guidelines suggest that chest compressions are less effective in TCA caused by hypovolaemia, cardiac tamponade or tension pneumothorax [1[■],12[■],13[■]]. In such situations, when a patient is attended by clinicians with the requisite skills and equipment to treat these potentially reversible causes, some guidelines suggest treatment of the underlying cause should be prioritized over chest compressions.

Ambulance Victoria undertook a retrospective study examining the effect of a new clinical guideline which prioritized controlling major external haemorrhage, securing the airway, bilateral chest decompression and a fluid challenge (20 ml kg⁻¹ 0.9% saline) ahead of chest compressions [14[■]]. Prior to the new guideline, patients with TCA were managed according to standard advanced life support guidelines (compressions, defibrillation, airway and drugs) ahead of correcting potentially reversible causes. 341 adults underwent resuscitation attempts for TCA during the control period (2008–2016) and

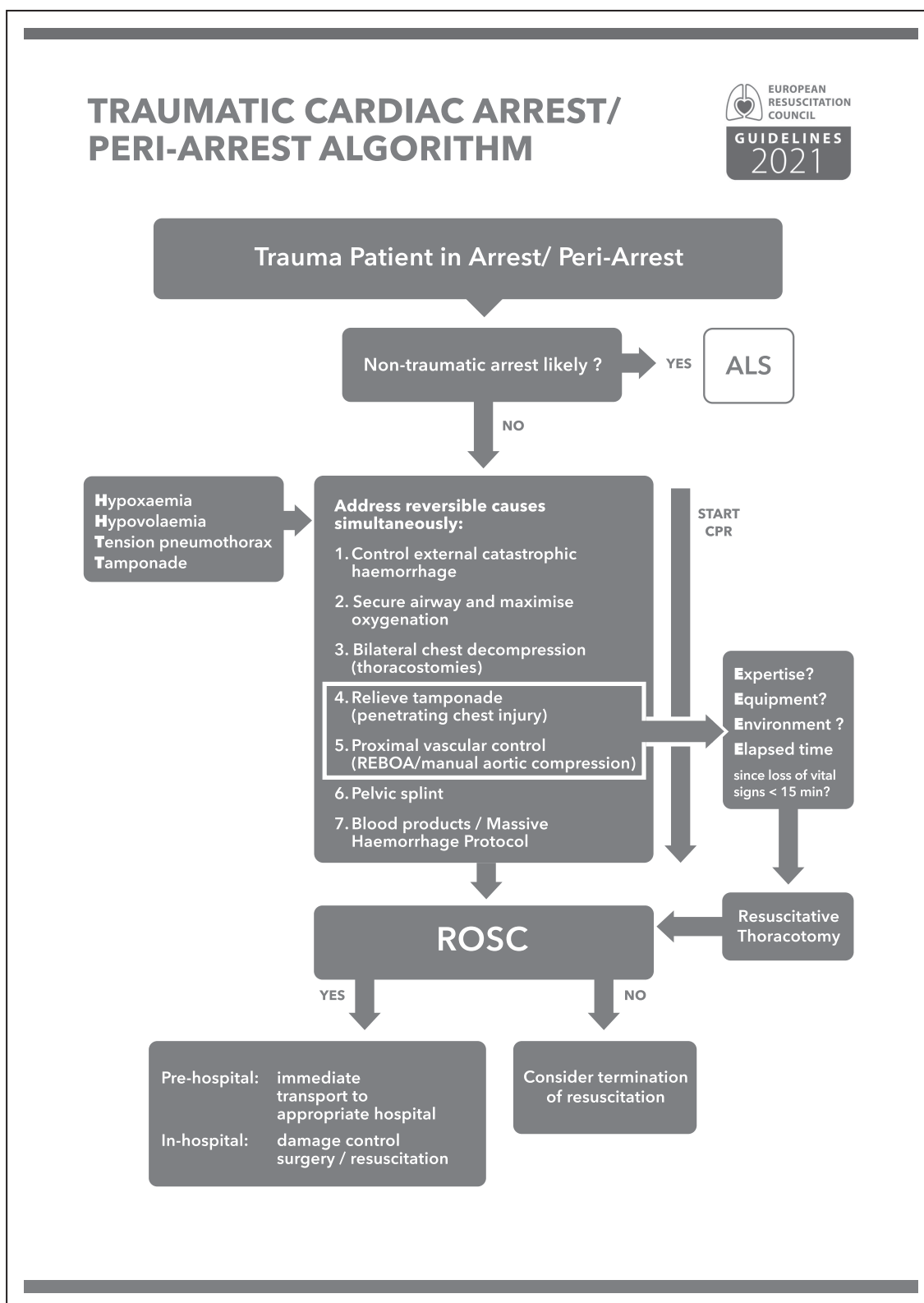


FIGURE 1. European Resuscitation Council treatment algorithm for traumatic cardiac arrest. Reproduced with permission from the European Resuscitation Council. Available at <https://www.cprguidelines.eu>.

149 following implementation of the new guideline (2017–2019). During the intervention period there was a significant increase in the delivery of almost all trauma-based interventions including external haemorrhage control, supraglottic airway device use, needle and finger thoracostomies, splinting, and administration of blood products. There was a concurrent decrease in the proportion of patients who received intra-arrest CPR and adrenaline. The time to adrenaline administration also more than doubled from 2.3 min to 5.8 min. The study found no difference in patient outcomes in both univariate and multivariate models for prehospital return of spontaneous circulation (ROSC) (27.5% in control period vs. 24.0% in the intervention period), survival to hospital admission (16.9% vs. 19.8%), and survival to hospital discharge (6.8% vs. 6.2%). The authors conclude that further research is required to determine if an approach which prioritises trauma-based interventions improves clinical outcomes.

Lee *et al.* examined a similar change to guidelines which prioritized the identification and treatment of reversible causes of cardiac arrest in patients with TCA presenting to an emergency department in Taiwan [9]. The study reported a higher rate of ROSC (41.5% vs. 23.6%, $P=0.035$) following implementation of the new guideline as well as a trend in improvement to survival to discharge (4.6% vs. 0.0%, $P=0.107$). Whether these findings are reproduced in other studies remains to be determined.

POINT OF CARE ULTRASOUND

Identifying the underlying pathology present in a patient presenting in TCA is essential for supporting resuscitation decision-making, as well as for guiding interventions with the aim of reversing cardiac arrest. A number of recent studies utilize Point of Care Ultrasound (POCUS) in an attempt to stratify prognosis for ‘all-cause’ TCA and guide subsequent resuscitative efforts both before and after ROSC.

Lalande *et al.* [15[■]] undertook a systematic review to identify whether POCUS can be used as a reliable predictor of outcome in traumatic arrest. The review identified seven studies involving 478 patients with TCA, which reported survival to hospital discharge. Amongst 369 patients with no cardiac activity seen on POCUS, none survived to hospital discharge (positive predictive value 100%). Of the 117 patients with evidence of cardiac activity, 8 survived to hospital discharge (7%). Significant heterogeneity between the studies reviewed prevented a clear change in practice guidelines being indicated. However, the absence of cardiac activity on POCUS examination was associated with a high likelihood of death.

No reviews were found which specifically addressed the role of POCUS to identify reversible causes in TCA. A retrospective observational study amongst 1497 patients who sustained a prehospital TCA and received resuscitation from attending paramedics noted low uptake of POCUS (13.5% of cases) and an association with poor outcome [2]. Given the observational nature of the study it is unknown if the association was casual or confounded by selection bias. The International Liaison Committee on Resuscitation review of POCUS covered cardiac arrest (all causes) and identified only very low certainty evidence from a single observational study leading to a treatment recommendation suggesting against the routine use of POCUS [10[■]]. If POCUS is undertaken, it is suggested that its use is limited to experienced operators, that interruptions in CPR are minimized and its use is limited to cases where clinical suspicion for a specific reversible cause is present [10[■]], as may be the case in some TCAs.

A single centre, retrospective study, conducted between 2014 to 2016 at a high-volume level 1 trauma centre examined the use of focussed assessment with sonography for trauma (FAST) by non-radiologists [9]. The study sought to identify abdominal haemorrhage amenable to abdominal surgical exploration following resuscitative thoracotomy and return of spontaneous circulation. The FAST scan identified 35 of 53 patients with haemoperitoneum (sensitivity 66.0%) and correctly ruled out haemoperitoneum in 89 of 105 cases (specificity 84.8%). The authors suggest these data support proceeding immediately to exploratory laparotomy in the presence of a positive FAST scan and diagnostic peritoneal aspirate if the FAST scan is negative.

TREATMENT

There was limited recent evidence identified relating to the treatment of TCA. Studies identified included the use of advanced life support (ALS) interventions, resuscitative thoracotomy and resuscitative endovascular balloon occlusion of the aorta (REBOA).

Advanced life support interventions

A small number of studies explored the impact of standard ALS interventions on outcomes in TCA. A large nationwide retrospective Japanese cardiac arrest registry review identified the impact of an advanced airway device, defined as an endotracheal tube or supraglottic airway device, on survival and ROSC rates [16[■]]. An advanced airway was associated with improved ROSC rates (21% vs. 11.4%) but had no impact on rates of overall survival to discharge.

A systematic review and meta-analysis identified 4 observational studies examining outcomes following out-of-hospital cardiac arrest amongst 1909 patients who received adrenaline compared to 5249 who did not during attempted resuscitation from TCA [17[■]]. No clear benefit for prehospital ROSC, in-hospital survival or short-term survival could be identified. An additional retrospective observational study explored outcomes amongst 2024 patients who sustained a blunt TCA following road traffic collision and were treated with adrenaline [18[■]]. Similar to findings from the PARAMEDIC2 study [19], the investigators found a time dependent relationship on survival relating to the timing of adrenaline administration. Early (6–21 min) adrenaline was associated with better outcomes with a survival rate of 3.2% falling to 0.2% with late adrenaline (35–60 min) with a *P*-value for trend of 0.0009. The observational nature of these studies alongside the risk of confounding due to resuscitation time bias [20], limits clear interpretation of the research findings.

Resuscitative thoracotomy and aortic compression

Resuscitative thoracotomy enables the release of cardiac tamponade, internal cardiac massage and aortic compression in cases of sub-diaphragmatic haemorrhage [12[■]]. A case series of 44 resuscitative thoracotomies in a single UK helicopter emergency medical service confirmed the feasibility of this technique outside a hospital. This study found that tamponade was more common in cases of penetrating trauma (39% penetrating vs. 15% blunt) though a higher than expected proportion of tamponade was seen in the blunt trauma cohort [21[■]]. Whilst ROSC was more common in the blunt trauma group (9/26, 34.6%) compared to penetrating trauma (2/16, 12.5%), no patients survived to hospital discharge.

In contrast, a retrospective, single centre observational study from Sweden reported a survival rate of 12/101 (12%) following emergency department thoracotomy [4[■]]. Whilst the shorter the time from cardiac arrest to thoracotomy the higher the chance of survival, 4 people survived despite a treatment delay of >15 min. However, all had severe neurological impairment at discharge (Glasgow Outcome Scale of 3 (lower severe disability) or 4 (higher severe disability) indicating a requirement for full or partial assistance in activities of daily living. There remains the need for further research to optimize the indications, setting and outcomes from this invasive treatment.

Resuscitative endovascular balloon occlusion of the aorta

A number of scoping reviews have been published examining the potential role for REBOA in the management of TCA [22[■],23,24[■]]. All identify that in cases of TCA secondary to noncompressible haemorrhage, there may be opportunity for improved patient outcomes. Increases in both cerebral perfusion, coronary perfusion and systolic blood pressures are reported across the cited literature. These findings are offset by the challenges of delivering this intervention, particularly in the prehospital environment and the mortality associated with long occlusion times. All reviews identified that the evidence remains weak overall with bias present throughout the literature. More conclusive evidence is required before strong clinical practice recommendations can be made in regard to the utility of REBOA in TCA. This intervention remains limited to a very small number of specialist teams both in and out of hospital, though this may expand if the evidence base improves.

CONCLUSION

Traumatic cardiac arrest remains a significant clinical challenge to manage, with survival to discharge rates below that of medical cardiac arrest. The complex interplay of pathologies that can result in TCA make targeting therapy difficult. Focussing on a core set of early interventions (oxygenation, fluid challenge, thoracic decompression and treatment of tamponade/noncompressible haemorrhage) ensures key priorities are addressed. The routine use of resuscitative thoracotomy and REBOA remains uncertain. Further high-quality studies are required before clear clinical recommendations can be made.

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Conflicts of interest

GDP holds editor roles with the journals Resuscitation and Resuscitation Plus. He has volunteer roles with the International Liaison Committee on Resuscitation (co-chair), European Resuscitation Council (Director of Science and Research) and Resuscitation Council UK (Vice-President).

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

- of special interest
- of outstanding interest

1. Soar J, Becker LB, Berg KM, *et al.* Cardiopulmonary resuscitation in special circumstances. *Lancet* 2021; 398:1257–1268.

State of the art narrative review of resuscitation in special circumstances. The article includes guidance on resuscitation from traumatic cardiac arrest, focusing on treatment of reversible causes. Guidance advises a stepwise approach starting with arresting catastrophic haemorrhage before assessing and treating airway, breathing, circulation and disability problems.

2. Doan TN, Wilson D, Rashford S, *et al.* Epidemiology, management and survival outcomes of adult out-of-hospital traumatic cardiac arrest due to blunt, penetrating or burn injury. *Emerg Med J* 2022; 39:111–117.
3. Lee MHM, Chia MYC, Fook-Chong S, *et al.* Characteristics and outcomes of traumatic cardiac arrests in the Pan-Asian Resuscitation Outcomes Study. *Prehosp Emerg Care* 2022; 1–9. [Online ahead of print]

Retrospective observational study from the Pan-Asian Resuscitation Outcomes Study (PAROS) clinical research network. Survival rates overall were 3.4% with 1% surviving with a favourable neurological outcome. The study highlights that in traumatic cardiac arrest early aggressive resuscitation may not be futile and bystander CPR improves outcomes.

4. Ohlén D, Hedberg M, Martinsson P, *et al.* Characteristics and outcome of traumatic cardiac arrest at a level 1 trauma centre over 10 years in Sweden. *Scand J Trauma Resusc Emerg Med* 2022; 30:54.

A single centre retrospective cohort study describing the outcomes of adults patients treated in an emergency department for traumatic cardiac arrest over a 10 year period. Survival rates of 12% were seen following emergency department thoracotomy showing the intervention is not futile. The earlier thoracotomy was done the better the outcome. However survival was still seen in four patients despite being in cardiac arrest for more than 15 min in contrast to the therapeutic window describe in current guidelines.

5. Soni KD, Rai N, Aggarwal R, Trikha A. Outcomes of trauma victims with cardiac arrest who survived to intensive care unit admission in a Level 1 Apex Indian Trauma Centre: a retrospective cohort study. *Indian J Crit Care Med* 2021; 25:1408–1412.

6. Vianen NJ, Van Lieshout EMM, Maissan IM, *et al.* Prehospital traumatic cardiac arrest: a systematic review and meta-analysis. *Eur J Trauma Emerg Surg* 2022; 48:3357–3372.

Systematic review and meta-analysis which summarises data from 51 722 patients (36 studies) who sustained a traumatic cardiac arrest. Survival rates varied depending on case definition with best outcomes seen in studies which excluded prehospital deaths. Although survival rates are lower than those typically seen for all-cause cardiac arrest, the study highlights that attempting resuscitation from traumatic cardiac arrest is not futile.

7. Seewald S, Wnent J, Gräsner JT, *et al.* Survival after traumatic cardiac arrest is possible—a comparison of German patient-registries. *BMC Emerg Med* 2022; 21:158.
8. Kitano S, Fujimoto K, Suzuki K, *et al.* Evaluation of outcomes after EMS-witnessed traumatic out-of-hospital cardiac arrest caused by traffic collisions. *Resuscitation* 2022; 171:64–70.
9. Ghafil C, Matsushima K, Guzman R, *et al.* Performance of focused assessment with sonography for trauma following resuscitative thoracotomy for traumatic cardiac arrest. *World J Surg* 2022; 46:91–97.
10. Wyckoff MH, Greif R, Morley PT, *et al.* 2022 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations: summary from the basic life support; advanced life support; pediatric life support; neonatal life support; education, implementation, and teams; and first aid task forces. *Resuscitation* 2022; 181:208–288.

The International Liaison Committee on Resuscitation Consensus on Science and Treatment Recommendations summarised the evidence for point of care ultrasound to identify reversible causes of cardiac arrest. There was very little evidence found in all-cause cardiac arrest and none specifically in patients with traumatic cardiac arrest. The treatment recommendation advises against the routine use of ultrasound to diagnose reversible pathology in all-cause cardiac arrest. Ultrasound use should be limited to experienced providers and patients where there is a high index of suspicion of a reversible cause. Care should be taken to minimise interruptions to resuscitation whilst ultrasound examination is performed.

11. Ordoobadi AJ, Peters GA, MacAllister S, *et al.* Prehospital care for traumatic cardiac arrest in the US: a cross-sectional analysis and call for a national guideline. *Resuscitation* 2022; 179:97–104.

12. Lott C, Truhlar A, Alfonzo A, *et al.* European Resuscitation Council Guidelines 2021: cardiac arrest in special circumstances. *Resuscitation* 2021; 161:152–219.

The European Resuscitation Council Guidelines include recommendations for the treatment of traumatic cardiac arrest. The guidelines highlight the importance of the identification and treatment of reversible causes. This requires the appropriate expertise, equipment and environment to deliver time critical interventions. Where injuries incompatible with life or where no signs of life have been present in the preceding 15 min, the guidelines suggest withholding resuscitation.

13. Tazarourte K, Ageron FX, Avondo A, *et al.* Prehospital trauma flowcharts – concise and visual cognitive aids for prehospital trauma management from the French Society of Emergency Medicine (SFMU) and the French Society of Anaesthesia and Intensive Care Medicine (SFAR). *Anaesth Crit Care Pain Med* 2022; 41:101070.

The French Society of Emergency Medicine and the French Society of Anaesthesia and Intensive Care Medicine developed trauma flow charts which provide comprehensive visual guidance for clinicians in the prehospital setting.

14. Alqudah Z, Nehme Z, Williams B, *et al.* Survival outcomes in emergency medical services witnessed traumatic out-of-hospital cardiac arrest after the introduction of a trauma-based resuscitation protocol. *Resuscitation* 2021; 168:65–74.

Ambulance Victoria (Melbourne Australia) introduced a new trauma guideline which prioritised treatment of reversible causes ahead of standard advanced life support interventions. This before and after study found no difference in survival following implementation of the new guideline.

15. Lalande E, Burwash-Brennan T, Burns K, *et al.* Is point-of-care ultrasound a reliable predictor of outcome during traumatic cardiac arrest? A systematic review and meta-analysis from the SHoC investigators. *Resuscitation* 2021; 167:128–136.

This systematic review identified studies where POCUS was used to identify cardiac activity during TCA. Patients with no identifiable cardiac movement were associated with a very high likelihood of death and a low chance of survival.

16. Nishimura T, Suga M, Nakao A, *et al.* Prehospital advanced airway management of emergency medical service-witnessed traumatic out-of-hospital cardiac arrest patients: analysis of nationwide trauma registry. *Acute Med Surg* 2022; 9:e786.

This retrospective analysis of the Japanese nationwide registry identified that use of endotracheal intubation or a supraglottic airway device was associated with improved rates of ROSC but saw no difference in overall survival.

17. Wongtanasarin W, Thepchinda T, Kasirawat C, *et al.* Treatment outcomes of epinephrine for traumatic out-of-hospital cardiac arrest: a systematic review and meta-analysis. *J Emerg Trauma Shock* 2021; 14:195–200.

This systematic review which included 4 observational studies found no improvement in short or long term outcomes in patients with traumatic cardiac arrest who were treated with adrenaline. Whether this is a causal effect or subject to confounding from resuscitation bias is uncertain.

18. Hosomi S, Kitamura T, Sobue T, *et al.* Association between timing of epinephrine administration and outcomes of traumatic out-of-hospital cardiac arrest following traffic collisions. *J Clin Med* 2022; 11:3564.

This retrospective study of 2024 records demonstrated a negative correlation between time of epinephrine administration and survival in TCA. Bias exists due to the observational nature of the study and a resuscitation time bias intrinsic to the dataset.

19. Perkins GD, Kenna C, Ji C, *et al.* The influence of time to adrenaline administration in the Paramedic 2 randomised controlled trial. *Intensive Care Med* 2020; 46:426–436.

20. Andersen LW, Grossestreuer AV, Donnino MW. “Resuscitation time bias” – a unique challenge for observational cardiac arrest research. *Resuscitation* 2018; 125:79–82.

21. Almond P, Morton SMOM, Durge N. A 6-year case series of resuscitative thoracotomies performed by a helicopter emergency medical service in a mixed urban and rural area with a comparison of blunt versus penetrating trauma. *Scand J Trauma Resusc Emerg Med* 2022;30:8.

This single centre study reported no survivors to hospital discharge following 44 prehospital thoracotomies. This highlights the importance of case selection and ensuring the right expertise, equipment and environment before undertaking this invasive procedure.

22. Soeyland T, Hollott JD, Garner A. External aortic compression in noncompressible truncal hemorrhage and traumatic cardiac arrest: a scoping review. *Ann Emerg Med* 2022; 79:297–310.

This scoping review highlighted a potential role for aortic compression in a range of models for haemorrhagic presentations. Complications are associated with prolonged occlusion times.

23. Aoki M, Abe T. Traumatic cardiac arrest: scoping review of utilization of resuscitative endovascular balloon occlusion of the aorta. *Front Med (Lausanne)* 2022; 9:888225.

24. Slot SAS, van Oostendorp SE, Schoonmade LJ, Geeraedts LMG. The role of REBOA in patients in traumatic cardiac arrest subsequent to hemorrhagic shock: a scoping review. *Eur J Trauma Emerg Surg* 2022. [Online ahead of print]

This scoping review discussed the utility of REBOA in TCA following exsanguination. Whilst improvement in vital signs was observed the review is limited by selection bias.